US009059514B2

(12) **United States Patent**
Sanford et al.

(10) **Patent No.: US 9,059,514 B2**
(45) **Date of Patent: Jun. 16, 2015**

(54) **STRUCTURES FOR SHIELDING AND MOUNTING COMPONENTS IN ELECTRONIC DEVICES**

(75) Inventors: **Emery A. Sanford**, San Francisco, CA (US); **Qingxiang Li**, Mountain View, CA (US); **Lijun Zhang**, San Jose, CA (US); **Anthony S. Montevirgen**, San Francisco, CA (US); **Teodor Dabov**, San Francisco, CA (US); **Erik G. P. de Jong**, San Francisco, CA (US); **Wey-Jiun Lin**, Los Altos Hills, CA (US)

(73) Assignee: **Apple Inc.**, Cupertino, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 229 days.

(21) Appl. No.: **13/524,997**

(22) Filed: **Jun. 15, 2012**

(65) **Prior Publication Data**

US 2013/0335275 A1 Dec. 19, 2013

Related U.S. Application Data

(60) Provisional application No. 61/652,796, filed on May 29, 2012.

(51) **Int. Cl.**

H01Q 1/24	(2006.01)
H01Q 1/42	(2006.01)
H01Q 1/38	(2006.01)

(52) **U.S. Cl.**

CPC ***H01Q 1/42*** (2013.01); *Y10T 29/49016* (2015.01); ***H01Q 1/243*** (2013.01); ***H01Q 1/38*** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/243; H01Q 1/38

USPC 343/702, 841, 878

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,791,827	B2 *	9/2004	Kuo	361/679.26
7,847,753	B2	12/2010	Ishibashi et al.	
7,889,139	B2 *	2/2011	Hobson et al.	343/702
8,059,039	B2	11/2011	Ayala Vazquez et al.	
8,269,677	B2 *	9/2012	Guterman et al.	343/702
8,551,672	B2 *	10/2013	Wang Chen	429/510
2009/0159412	A1 *	6/2009	Liu et al.	200/302.3
2011/0050509	A1 *	3/2011	Ayala Vazquez et al.	343/702
2011/0212288	A1	9/2011	McClure et al.	
2012/0087065	A1	4/2012	Kim et al.	

* cited by examiner

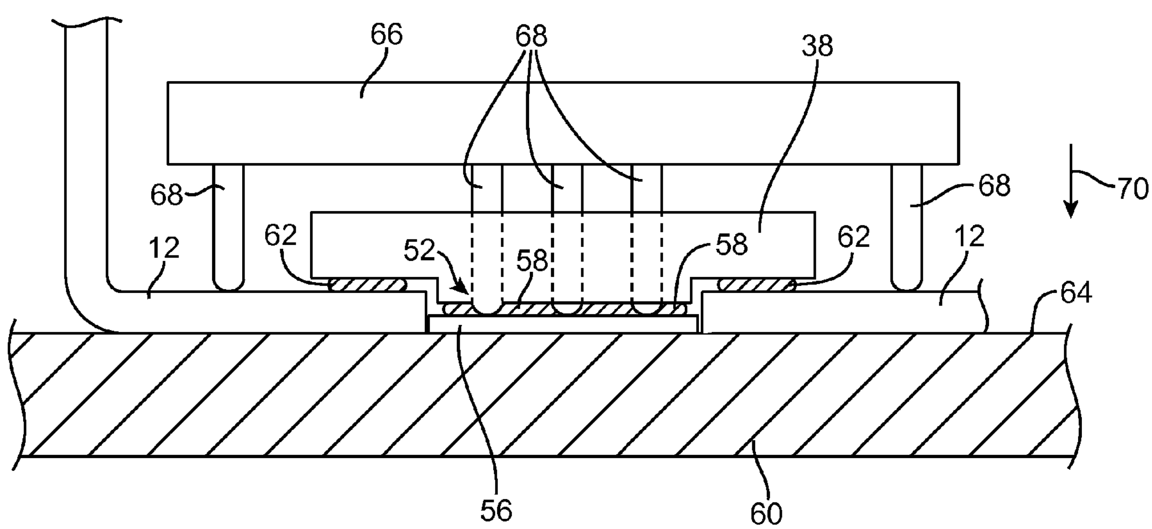
Primary Examiner — Tho G Phan

(74) *Attorney, Agent, or Firm* — Treyz Law Group; G. Victor Treyz; Joseph F. Guihan

(57) **ABSTRACT**

An electronic device may be provided with a conductive housing. An antenna window structure may be formed in an opening in the housing. The antenna window structure may have an antenna support structure that is attached to the conductive housing and that supports antenna structures. An antenna window cap may be mounted in the opening and attached to the antenna support structure with liquid adhesive. Alignment structures may be provided in the antenna support structure. An antenna support plate with mating alignment structures may be used in attaching the antenna structures to the antenna support structures. Metal shielding structures may be used to provide electromagnetic shielding. A shielding wall may be formed from a sheet metal structure supported by a plastic support structure. A flexible metal shielding foil layer may be welded to the shielding wall using a sacrificial plate.

27 Claims, 14 Drawing Sheets



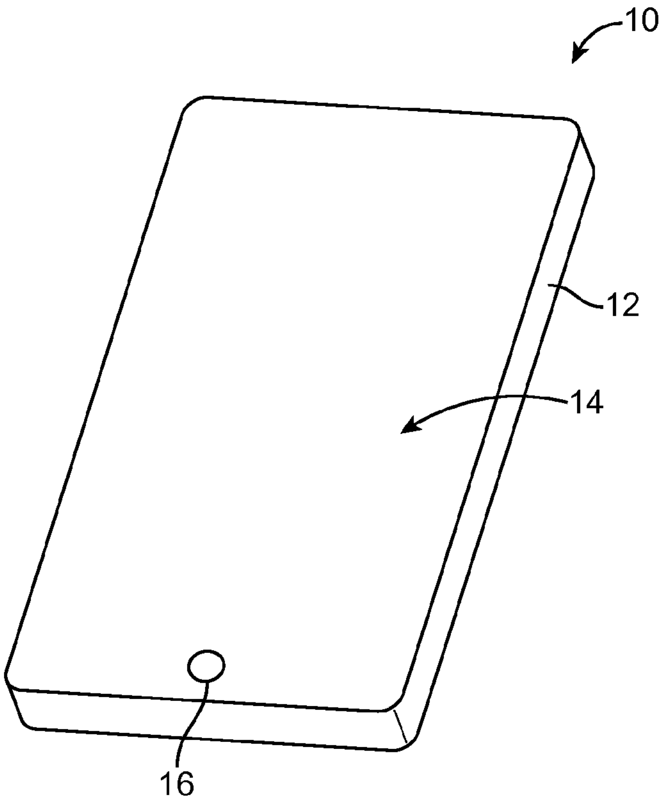


FIG. 1

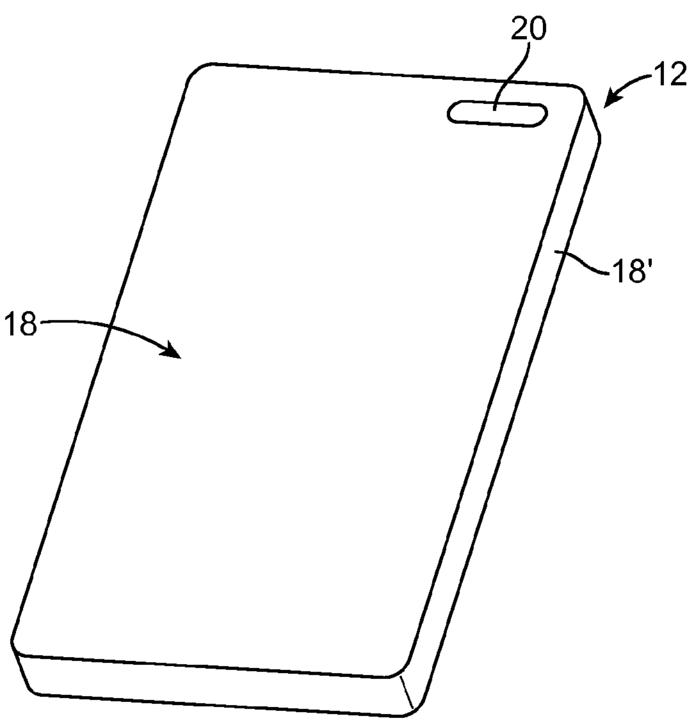


FIG. 2

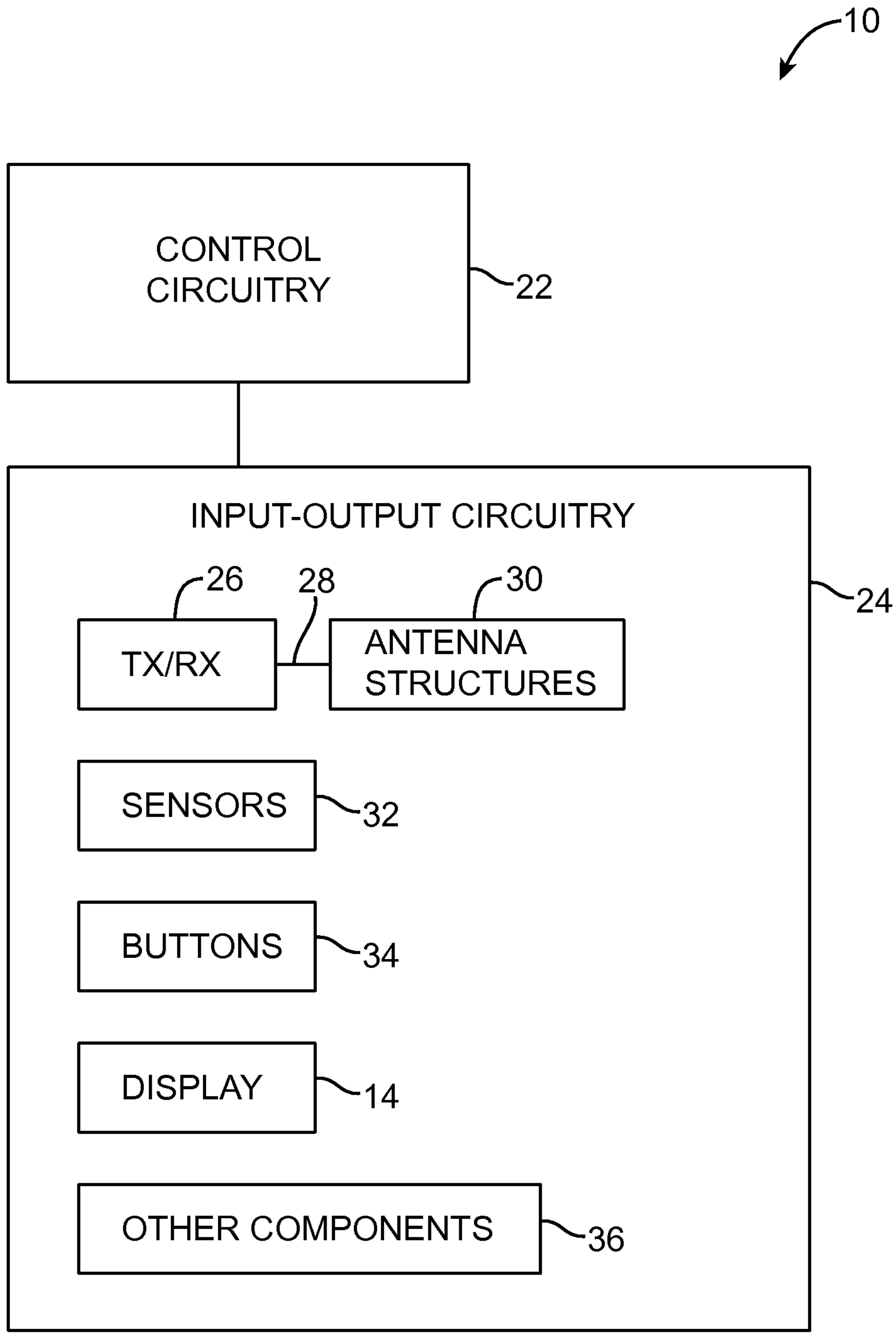

10
CONTROL CIRCUITRY
22
INPUT-OUTPUT CIRCUITRY
24
26
28
30
TX/RX
ANTENNA STRUCTURES
SENSORS
32
BUTTONS
34
DISPLAY
14
OTHER COMPONENTS
36

FIG. 3

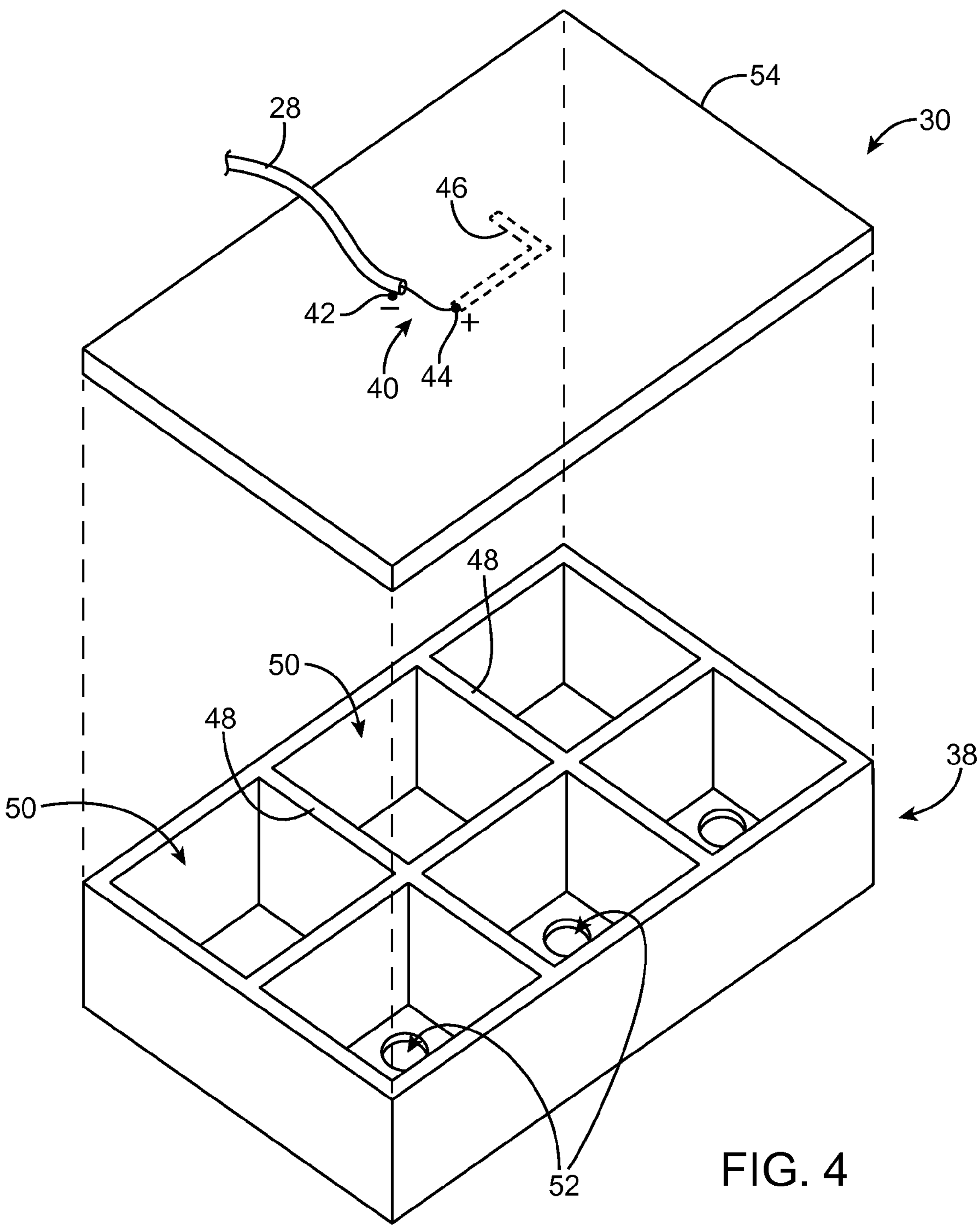


FIG. 4

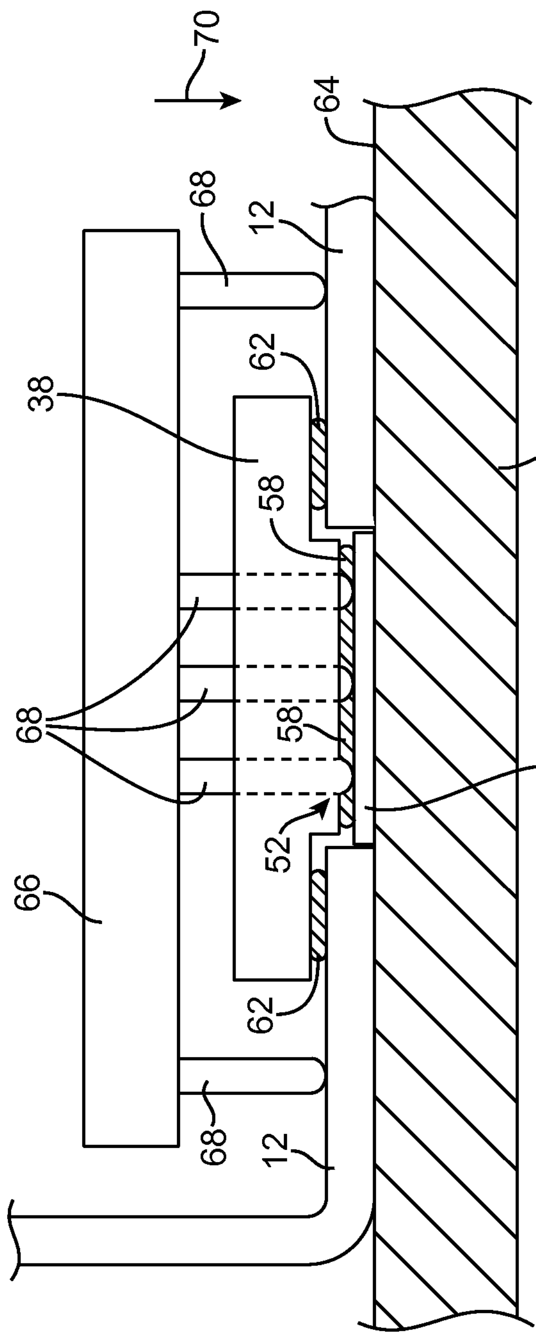


FIG. 5

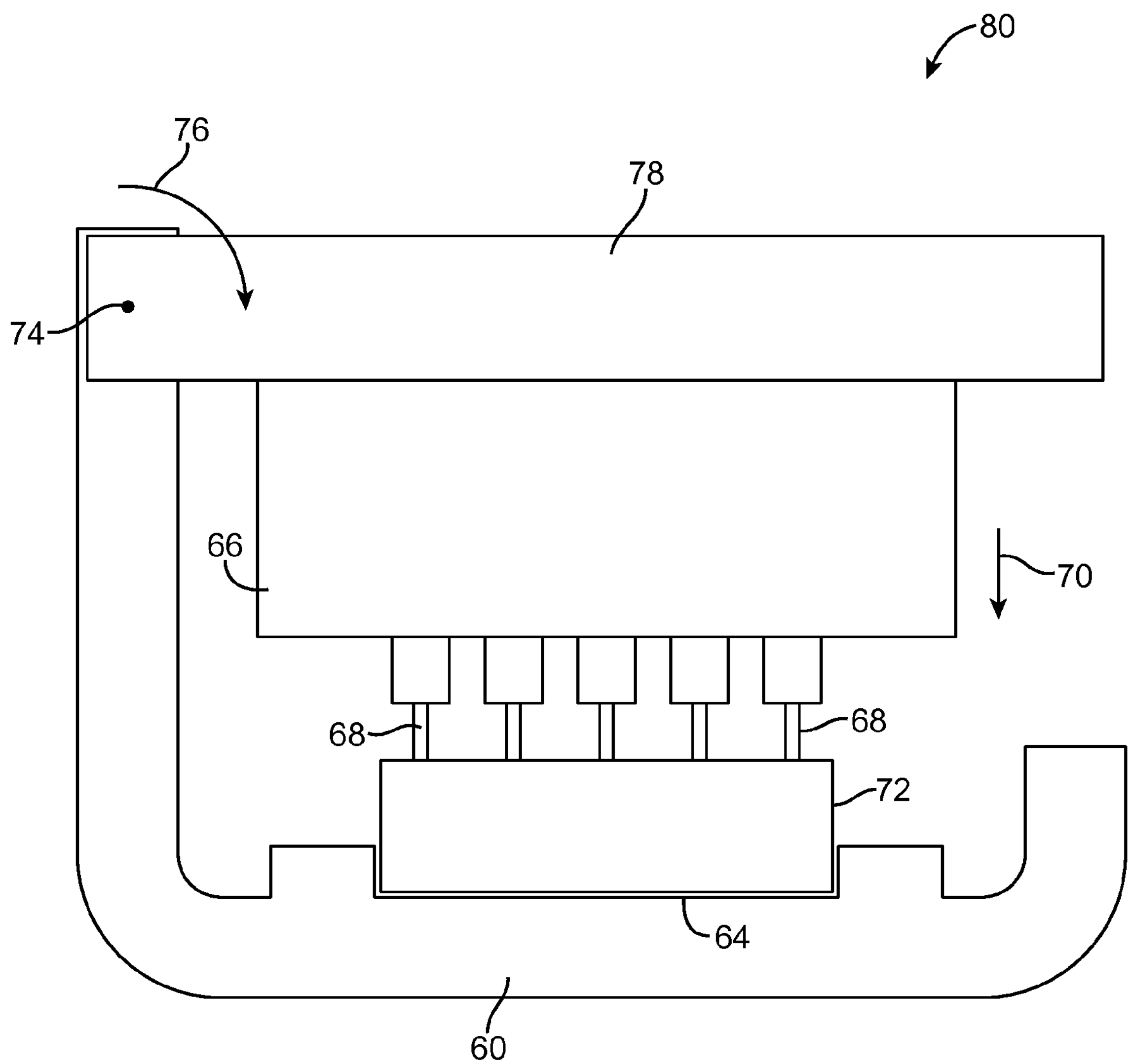


FIG. 6

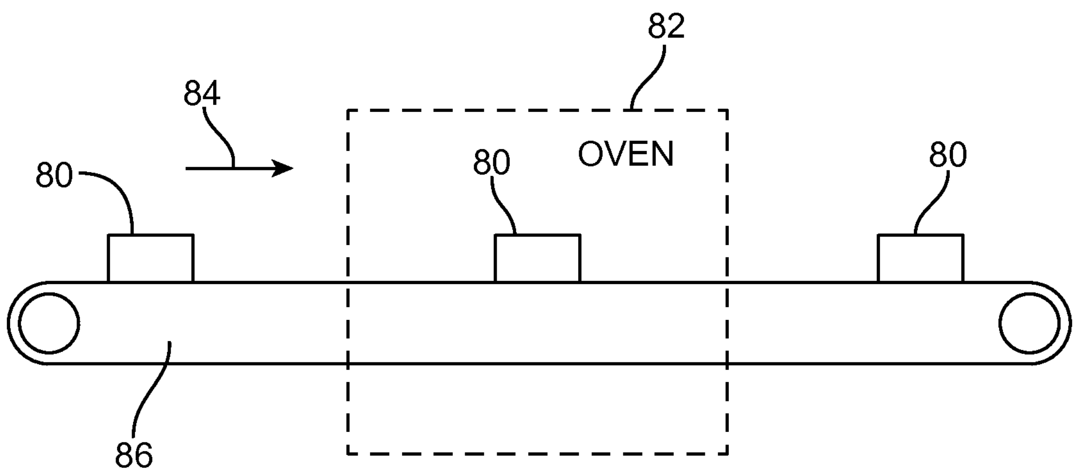


FIG. 7

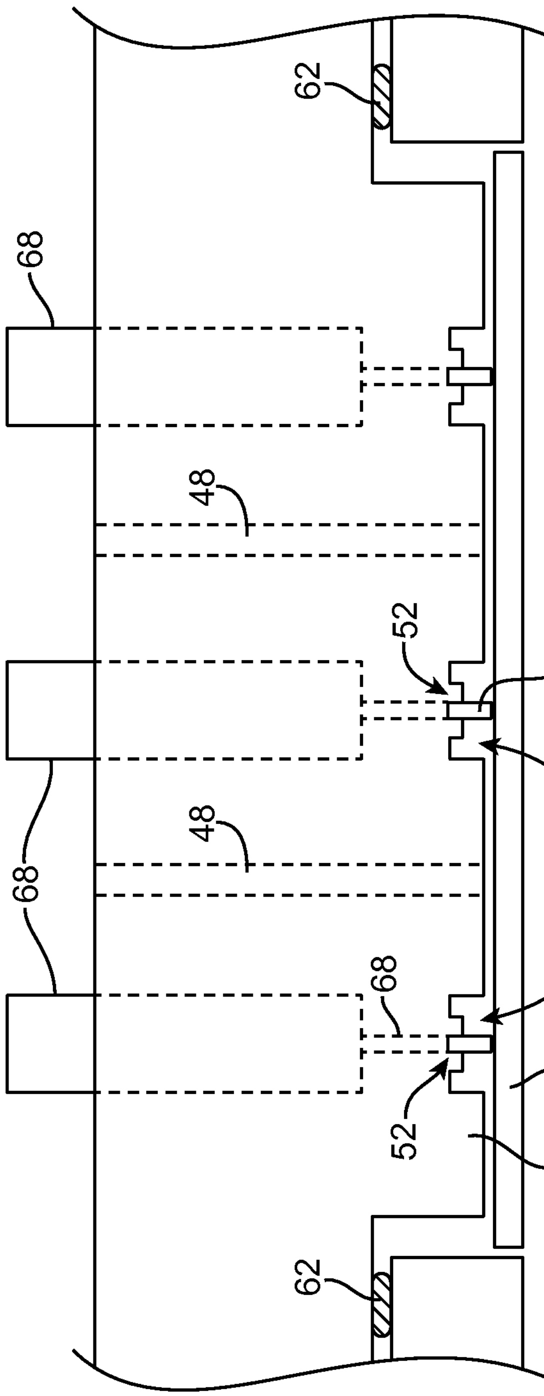


FIG. 8

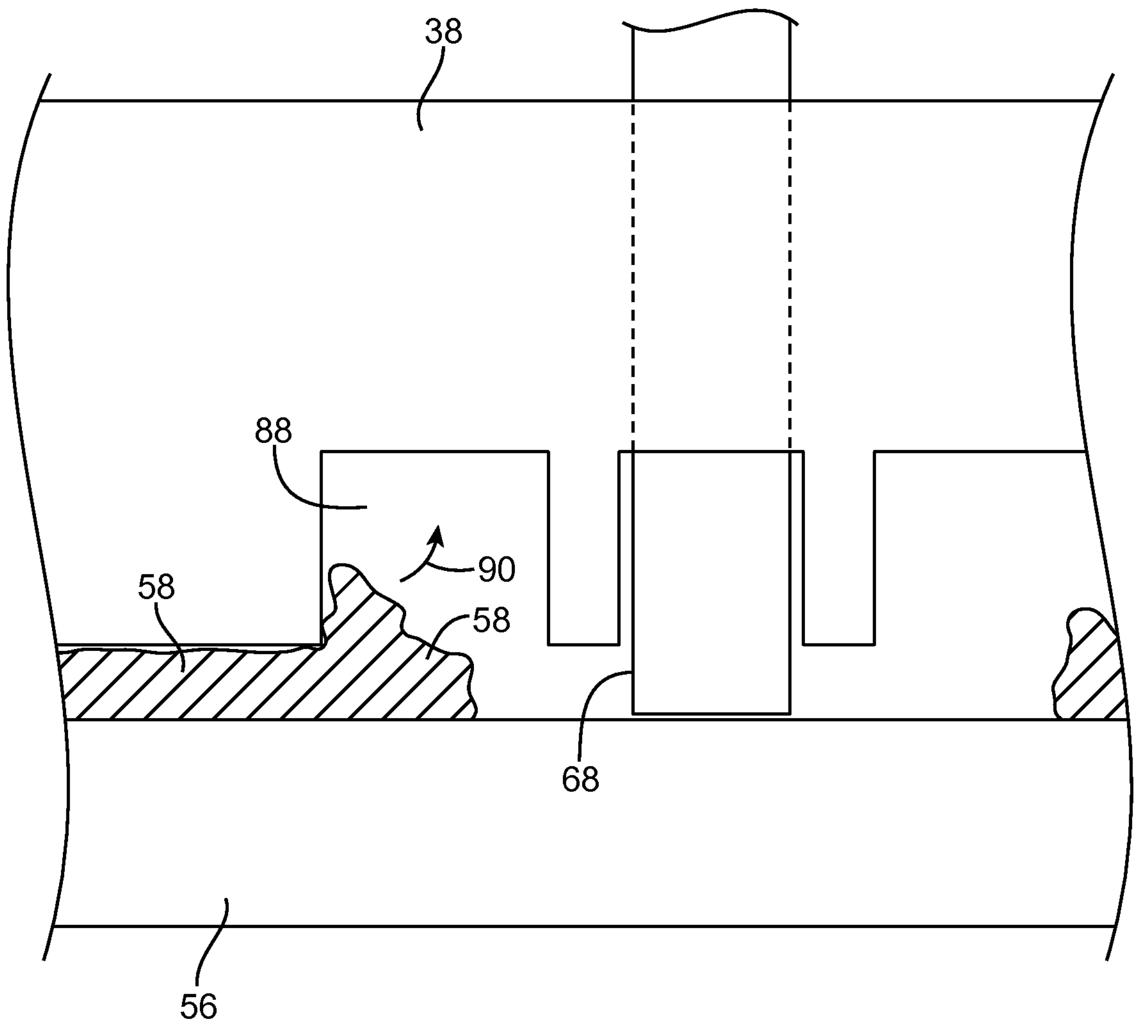


FIG. 9

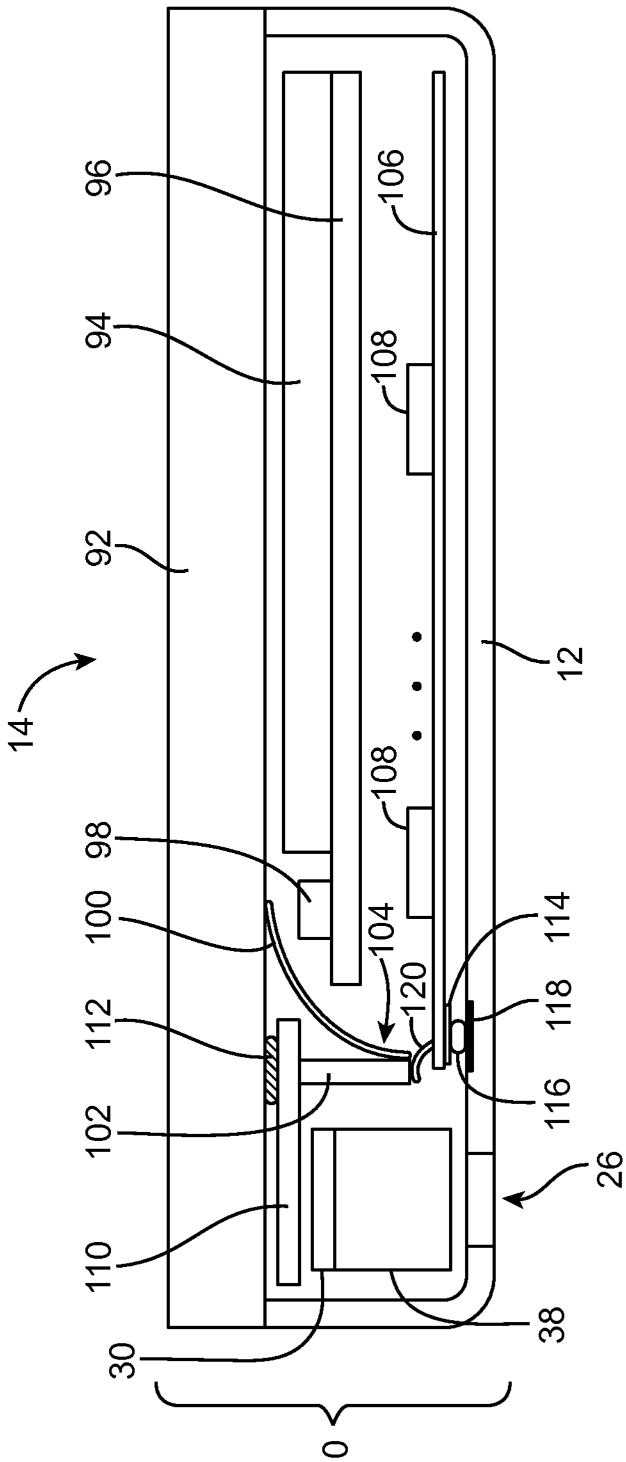

96
106
94
108
92
12
14
108
98
100
104
120
114
118
112
116
102
26
110
38
30
10

FIG. 10

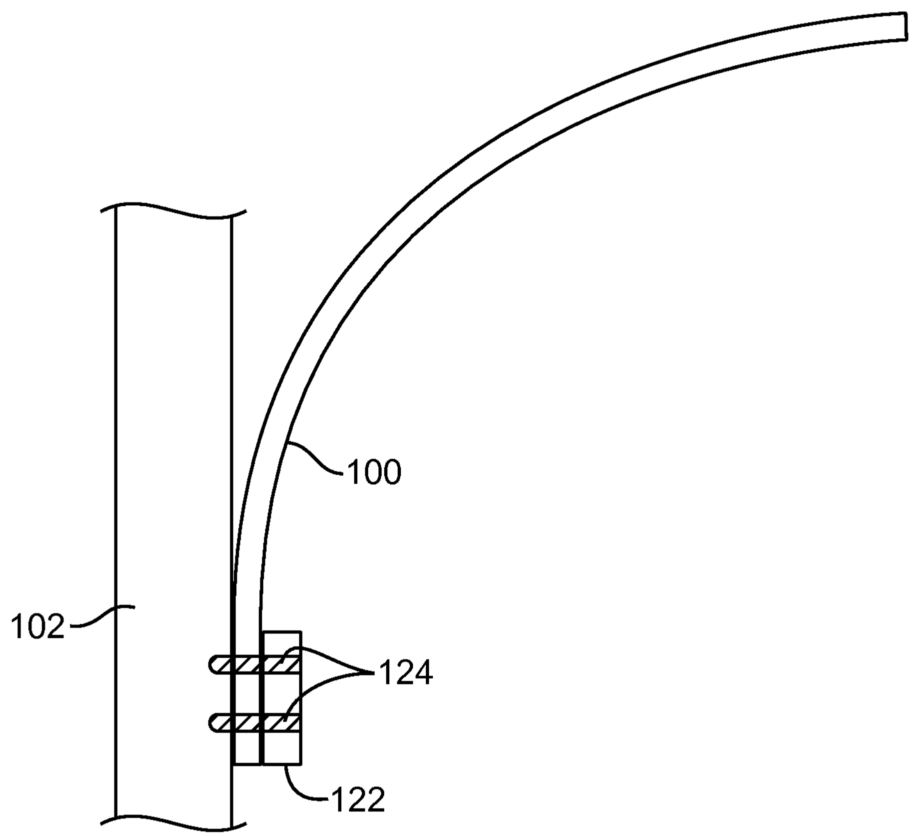


FIG. 11

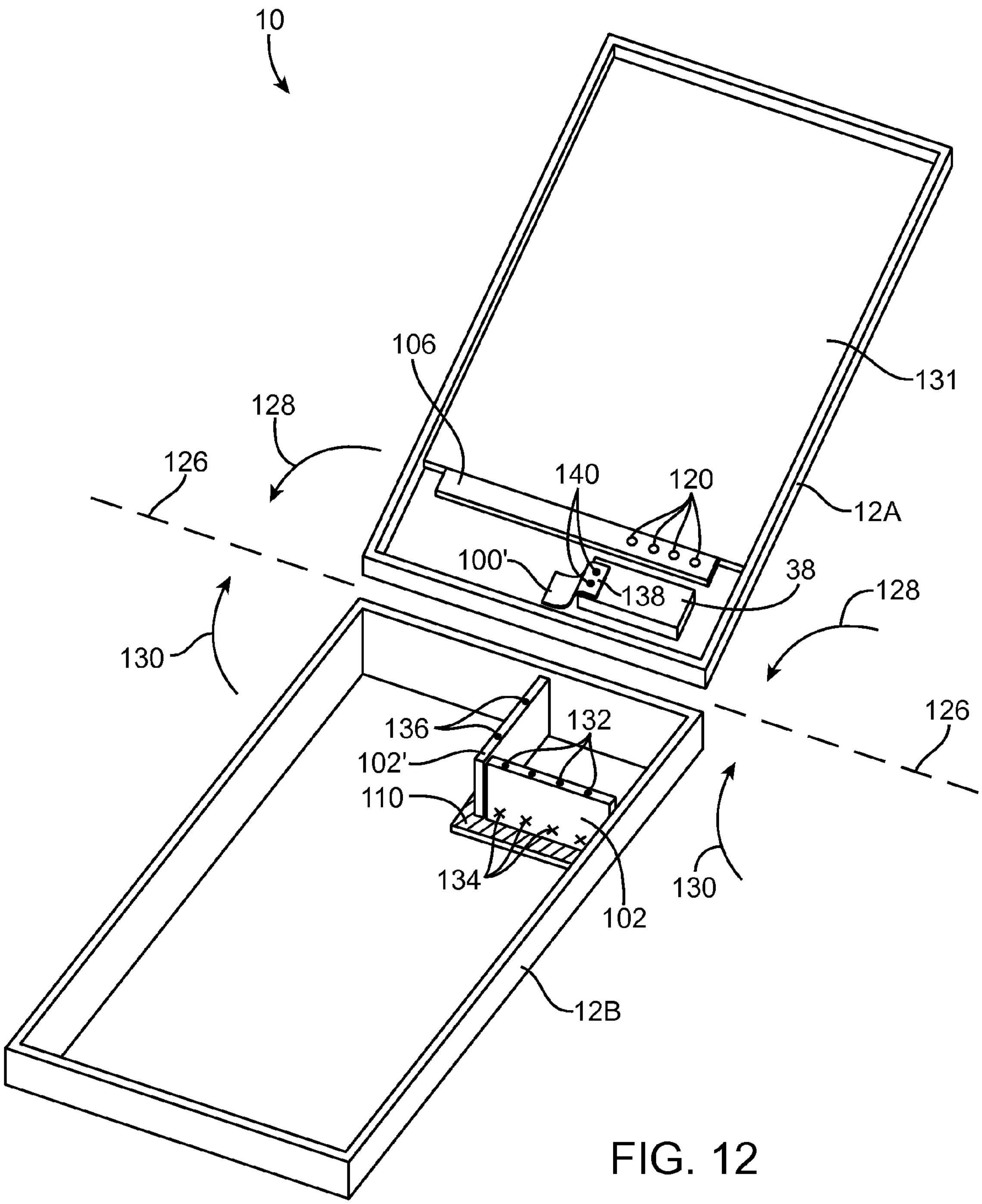

10
106
131
128
126
140
120
12A
100'
138
38
128
130
126
136
132
102'
110
134
130
102
12B

FIG. 12

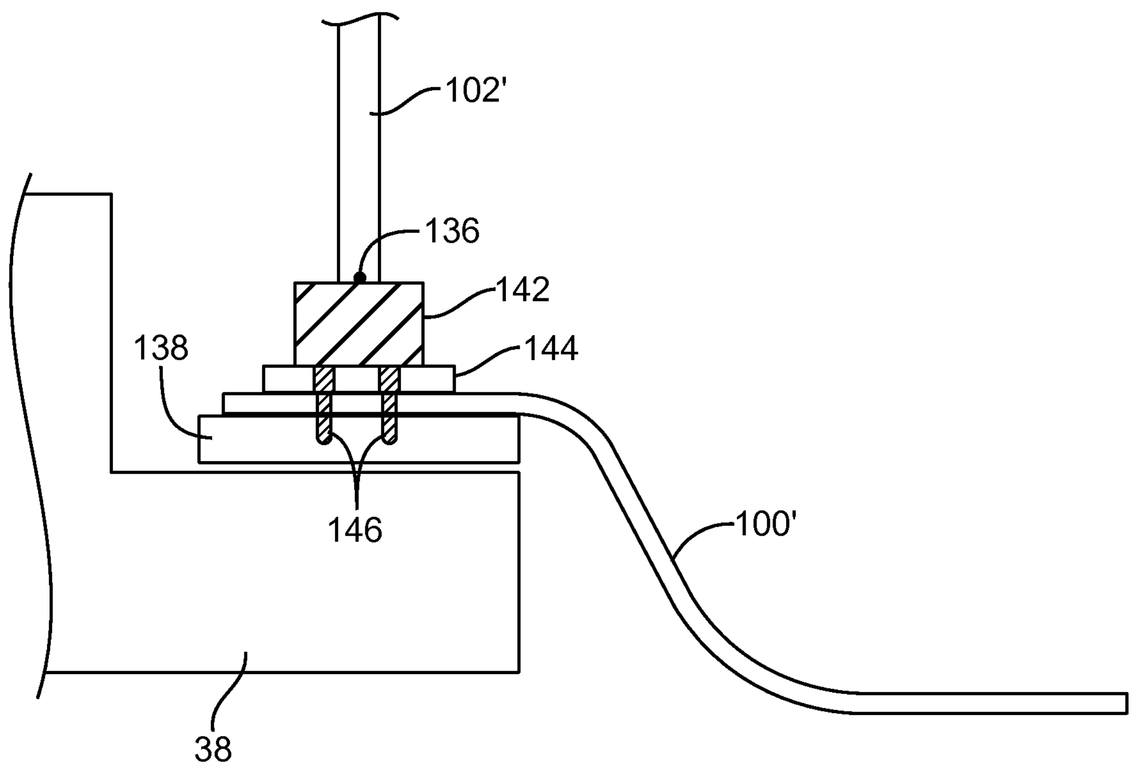


FIG. 13

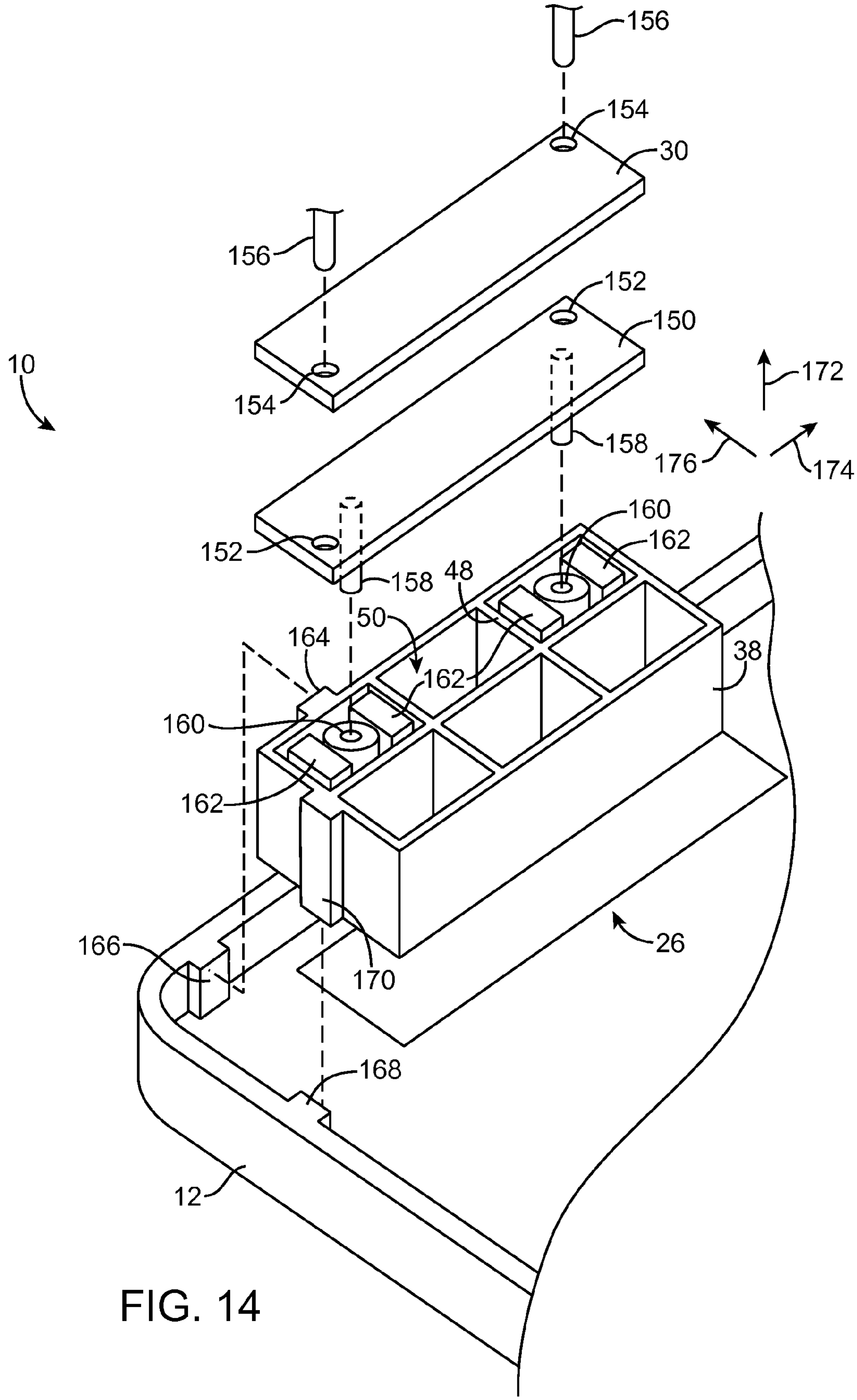

156
154
30
156
152
150
10
154
172
158
176
174
160
162
152
158
48
50
164
38
162
160
162
166
26
170
168
12

FIG. 14

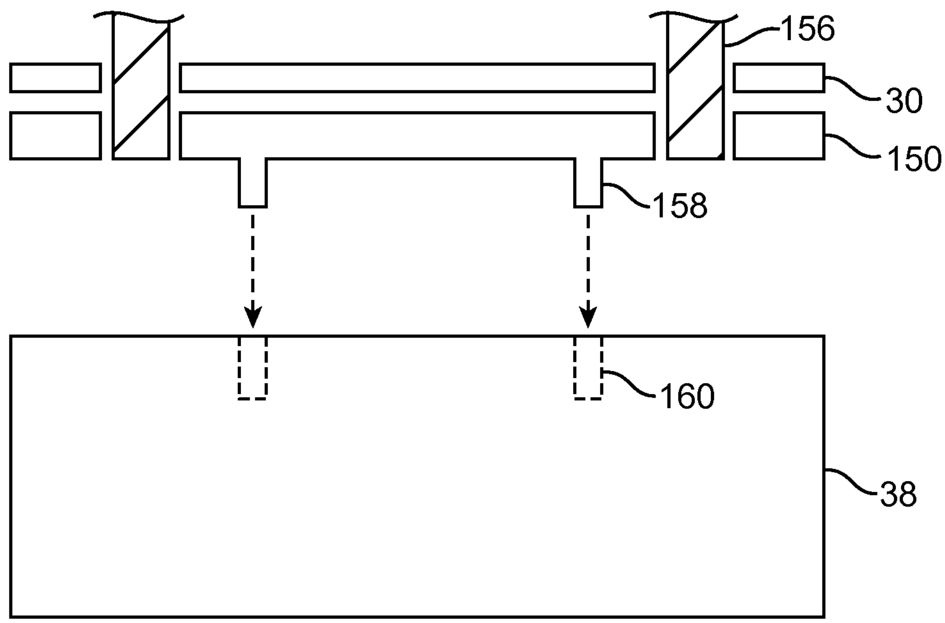


FIG. 15

STRUCTURES FOR SHIELDING AND MOUNTING COMPONENTS IN ELECTRONIC DEVICES

This application claims the benefit of provisional patent application No. 61/652,796, filed May 29, 2012, which is hereby incorporated by reference herein in its entirety.

BACKGROUND

This relates to electronic devices and, more particularly, to antenna structures and electromagnetic shielding structures for electronic devices.

Electronic devices often contain wireless circuitry. For example, cellular telephone transceiver circuitry and wireless local area network circuitry may be provided to allow a device to wirelessly communicate with external equipment. Antenna structures may be used in transmitting and receiving wireless signals.

Devices may also contain displays and other circuits that may interfere with wireless circuitry. To properly ground antenna structures and to provide electromagnetic shielding to reduce the impact of potentially harmful electromagnetic interference, it may be desired to incorporate electromagnetic shielding structures in an electronic device. Care should be taken, however, to avoid structures that are unnecessarily bulky, that provide unsatisfactory grounding, or that provide inadequate suppression of electromagnetic interference.

It would therefore be desirable to be able to provide improved structures for mounting antennas in electronic devices and providing electromagnetic shielding.

SUMMARY

An electronic device may be provided with a conductive housing. An antenna window structure may be formed in an opening in the housing. The antenna window structure may have an antenna support structure that is attached to the conductive housing. Antenna structures such as antenna structures formed from traces on a printed circuit may be mounted on the antenna support structure. An antenna window cap may be mounted in the opening of the conductive housing. The antenna window cap may be attached to the antenna support structure with liquid adhesive that allows the antenna window cap to lie flush with an exterior surface of the conductive housing during adhesive curing operations, thereby improving flushness.

Alignment structures may be provided in the antenna support structure. An antenna support plate with mating alignment structures may be used in attaching the antenna structures to the antenna support structures. Ribs on the antenna support structure may serve as alignment features that bear against corresponding rib-shaped alignment features on the conductive housing.

Metal shielding structures may be used to provide electromagnetic shielding in the electronic device. Shielding walls may be formed from sheet metal structures supported by a plastic support structure. End portions of the shielding walls may be embedded within the plastic support structure during an insert molding process.

A flexible shielding layer formed from a thin metal sheet may be welded to a shielding wall. The thin metal sheet may have a thickness of less than 20 microns. To prevent damage during welding, a sacrificial plate may be incorporated into the welded structure. Conductive structures such as springs on printed circuits and conductive foam may be used in connecting shielding structures to a conductive electronic device housing.

Further features of the invention, its nature and various advantages will be more apparent from the accompanying drawings and the following detailed description of the preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a front perspective view of an illustrative electronic device of the type that may contain mounting, grounding, and shielding structures in accordance with an embodiment of the present invention.

FIG. **2** is a rear perspective view of the electronic device of FIG. **1** in accordance with an embodiment of the present invention.

FIG. **3** is a schematic diagram of an illustrative electronic device in accordance with an embodiment of the present invention.

FIG. **4** is a perspective view of an illustrative antenna support structure and an associated flexible printed circuit antenna structure in accordance with an embodiment of the present invention.

FIG. **5** is a cross-sectional side view of a portion of an electronic device in which a dielectric antenna window has been formed in accordance with an embodiment of the present invention.

FIG. **6** is a side view of an illustrative fixture for holding electronic device structures of the type shown in FIG. **5** during liquid adhesive curing operations in accordance with an embodiment of the present invention.

FIG. **7** is a cross-sectional side view of an illustrative conveyor belt system for conveying fixtures of the type shown in FIG. **6** through an oven to cure adhesive used in mounting an antenna window structure within an electronic device in accordance with an embodiment of the present invention.

FIG. **8** is a cross-sectional side view of an illustrative system for holding an antenna window cap in a position that is flush with an electronic device housing during adhesive curing operations in accordance with an embodiment of the present invention.

FIG. **9** is a side view of a portion of an illustrative antenna window structure and associated antenna support structure showing how the antenna support structure may have adhesive overflow channels in accordance with an embodiment of the present invention.

FIG. **10** is a cross-sectional side view of an electronic device showing how conductive foil structures may be used to provide antenna grounding and electromagnetic interference suppression in accordance with an embodiment of the present invention.

FIG. **11** is a cross-sectional side view of a portion of a conductive shielding wall and an associated welded metal foil layer in accordance with an embodiment of the present invention.

FIG. **12** is an exploded perspective view of an illustrative electronic device having conductive structures for antenna grounding and electromagnetic shielding in accordance with an embodiment of the present invention.

FIG. **13** is a cross-sectional side view of a portion of the conductive structures in FIG. **12** showing how a coupling structure such as conductive foam may be used to electrically connect shielding structures in accordance with an embodiment of the present invention.

FIG. **14** is a perspective view of a corner portion of an electronic device having antenna structures in accordance with an embodiment of the present invention.

FIG. **15** is a cross-sectional side view of the antenna structures of FIG. **14** during assembly using support structures in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION

Electronic devices often contain circuitry that is subject to potential electromagnetic interference effects. To suppress electromagnetic interference, it may be desirable to provide an electronic device with metal structures that serve as electromagnetic shields. The metal structures may be used to short conductive structures together. For example, metal structures may be used to provide a grounding path for an antenna. Metal structures may be interposed between circuits that handle potentially interfering signals. For example, the metal structures may be used to form a shield layer between a potential source of interference such as a display driver circuit in a display and a potential victim device such as an antenna.

Metal structures that may be used for shorting structures in a device together, that may be used for antenna grounding, and that may form walls and other structure that reduce electromagnetic interference may sometimes be referred to herein as shielding structures or electromagnetic interference shielding structures. Metal structures such as these may be formed from stamped sheet metal parts, from flexible metal foil, or from other conductive structures. These metal structures may be used for grounding antennas or other wireless components, may be used to prevent electromagnetic signals in one portion of a device from reaching another portion of a device, may be used to short metal structures together such as metal housing structures, or may otherwise be used in managing electrical signals in an electronic device.

An antenna in an electronic device may be mounted under an antenna window structure. For example, an electronic device may have a metal housing with an opening to accommodate antenna signals. The opening may be filled with a dielectric material such as plastic. The plastic may be configured to form an antenna window cap that floats within the opening. Adhesive may be used to attach the antenna cap to an internal structure such as an antenna support structure using adhesive. A fixture may be used to ensure that the antenna window cap structure and adjacent portions of the metal housing are flush before curing the adhesive. The adhesive may be a liquid adhesive having a thickness than can vary to accommodate variations in the sizes of the antenna window structures while maintaining flushness of the antenna window cap to the housing.

An illustrative device of the type that may include antenna window structures and electromagnetic shielding structures such as these is shown in FIG. **1**. As shown in FIG. **1**, electronic device **10** may include a display such as display **14**. Display **14** may be a touch screen that incorporates a layer of conductive capacitive touch sensor electrodes or other touch sensor components or may be a display that is not touch-sensitive. Display **14** may include an array of display pixels formed from liquid crystal display (LCD) components, an array of electrophoretic display pixels, an array of plasma display pixels, an array of organic light-emitting diode display pixels, an array of electrowetting display pixels, or display pixels based on other display technologies. Configurations in which display **14** includes display layers that form liquid crystal display (LCD) pixels may sometimes be described herein as an example. This is, however, merely illustrative. Display **14** may include display pixels formed using any suitable type of display technology.

Display **14** may be protected using a display cover layer such as a layer of transparent glass or clear plastic. Openings may be formed in the display cover layer. For example, an opening may be formed in the display cover layer to accommodate a button such as button **16**.

Device **10** may have a housing such as housing **12**. Housing **12**, which may sometimes be referred to as an enclosure or case, may be formed of plastic, glass, ceramics, fiber composites, metal (e.g., stainless steel, aluminum, etc.), other suitable materials, or a combination of any two or more of these materials.

Housing **12** may be formed using a unibody configuration in which some or all of housing **12** is machined or molded as a single structure or may be formed using multiple structures (e.g., an internal frame structure, one or more structures that form exterior housing surfaces, etc.). The periphery of housing **12** may, if desired, include walls. For example, housing **12** may have a peripheral conductive member such as a metal housing sidewall member that runs around some or all of the periphery of device **10** or may have a display bezel that surrounds display **14**. Housing **12** may have sidewalls that are curved, sidewalls that are planar, sidewalls that have a combination of curved and flat sections, sidewalls that extend upwards from an integral rear housing surface, and sidewalls of other suitable shapes. One or more openings may be formed in housing **12** to accommodate connector ports, buttons, and other components.

As shown in the front perspective view of FIG. **1**, display **14** may be mounted on the front face of device **10**. As shown in the rear perspective view of FIG. **2**, device **10** may have a rear housing member such as rear planar housing wall **18**. Wall **18** may be formed from a planar plastic structure, a planar metal structure, a glass layer, ceramics, or other materials. As an example, wall **18** and sidewalls **18'** may form integral portions of housing **12** and may be formed from aluminum, stainless steel, or other metals. Openings may be formed in rear wall surface **18**. For example, an opening may be formed in rear wall surface **18** of housing **12** (and, if desired, sidewalls **18'**) to accommodate antenna window **20**. The structures for antenna window **20** may be formed from glass, ceramic, polymer (plastic) or other suitable dielectric materials. As an example, antenna window **20** may be formed from a plastic such as polycarbonate (PC), acrylonitrile butadiene styrene (ABS), or a PC/ABS blend (as examples).

A schematic diagram of an illustrative configuration that may be used for electronic device **10** is shown in FIG. **3**. As shown in FIG. **3**, electronic device **10** may include control circuitry **22** and input-output circuitry **24**. Control circuitry **22** may include storage and processing circuitry that is configured to execute software that controls the operation of device **10**. Control circuitry **22** may be implemented using one or more integrated circuits such as microprocessors, application specific integrated circuits, memory, and other storage and processing circuitry.

Input-output circuitry **24** may include components for receiving input from external equipment and for supplying output. For example, input-output circuitry **24** may include user interface components for providing a user of device **10** with output and for gathering input from a user. As shown in FIG. **3**, input-output circuitry **24** may include wireless circuitry such as radio-frequency transceiver **26**. Radio-frequency transceiver **26** may include a radio-frequency receiver and/or a radio-frequency transmitter. Radio-frequency transceiver circuitry **26** may be used to handle wireless signals in communications bands such as the 2.4 GHz and 5 GHz

WiFi® bands, cellular telephone bands, and other wireless communications frequencies of interest.

Radio-frequency transceiver circuitry **26** may be coupled to one or more antennas in antenna structures **30** using one or more transmission lines such as radio-frequency transmission line **28**. Transmission lines in device **10** may be formed from one or more segments of coaxial cable, flexible printed circuit transmission lines, microstrip transmission lines, or edge coupled transmission lines (as examples). Antenna structures **30** may include inverted-F antennas, patch antennas, loop antennas, monopoles, dipoles, or other suitable antennas.

Sensors **32** may include an ambient light sensor, a proximity sensor, touch sensors such as a touch sensor array for a display and/or touch buttons, pressure sensors, temperature sensors, accelerometers, gyroscopes, and other sensors.

Buttons **34** may include sliding switches, push buttons, menu buttons, buttons based on dome switches, keys on a keypad or keyboard, or other switch-based structures.

Display **14** may be a liquid crystal display, an organic light-emitting diode display, an electrophoretic display, an electrowetting display, a plasma display, or a display based on other display technologies.

Device **10** may also contain other components **36** (e.g., communications circuitry for wired communications, status indicator lights, vibrators, etc.).

Antennas may include conductive structures supported on one or more support structures. Metal housing structures such as internal or external housing structures may also be used in forming antenna structures. As an example, a metal housing in device **10** such as some or all of housing wall structures **12** may form an antenna ground structure for an antenna. Conductive materials such as metal may be supported on dielectric substrates such as injection-molded plastic carriers, glass or ceramic members, or other dielectrics. As an example, patterned metal traces for an antenna resonating element and/or parasitic antenna resonating element may be formed on printed circuit substrates. An antenna may be formed, for example, using metal traces on a printed circuit such as a rigid printed circuit board (e.g., fiberglass-filled epoxy) or a flexible printed circuit formed from a sheet of polyimide or other flexible polymer layers. Antenna structures that are formed on printed circuit substrates may be supported by support structures such as plastic support structures or other dielectric support structures.

Illustrative antenna structures for electronic device **10** are shown in FIG. **4**. As shown in FIG. **4**, antenna structures **30** may be supported using antenna support structures such as antenna support structure **38**. Antenna structures **30** may be formed from a printed circuit substrate such as printed circuit **54**. Printed circuit **54** may include patterned metal traces **46**. Antenna structures **30** may form an antenna having an antenna feed such as antenna feed **40**. Antenna feed **40** may have a positive antenna feed terminal such as feed terminal **44** and a ground antenna feed terminal such as ground feed terminal **42**. Transmission line **28** (e.g., a coaxial cable) may have a positive center conductor that is coupled to terminal **44** and an outer braid ground conductor that is coupled to terminal **42** (as an example).

Antenna structures **30** may be mounted on antenna support structures **38** using adhesive, screws or other fasteners and may be mounted using interposed plastic plates and other support structures.

Antenna support structure **38** may be formed from a dielectric such as glass, ceramic, plastic, or other dielectric materials. As an example, antenna support structure **38** may be formed from one or more injection-molded plastic members such as plastic members formed from a plastic such as polycarbonate (PC), acrylonitrile butadiene styrene (ABS), or a PC/ABS blend.

Plastic structure **38** may include ribs **48** that separate the interior of structure **38** into air-filled cavities such as cavities **50**. The use of air-filled cavities in structure **38** may help to lower the dielectric constant of support structure **38** and reduce antenna losses.

Support structure **38** may be provided with one or more openings such as openings **52**. Openings (holes) **52** may be used during assembly of an antenna window structure such as antenna window structure **20** of FIG. **2** (as an example).

As shown in the cross-sectional side view of FIG. **5**, antenna window **26** of device **10** may be covered with a dielectric antenna window structure such as plastic antenna window cap structure **56** of FIG. **5** (sometimes referred to as an antenna window cap). Antenna window cap **56** may be formed from a plastic such as polycarbonate (PC), acrylonitrile butadiene styrene (ABS), or a PC/ABS blend (as examples).

Antenna support structure **38** may be attached to the interior of electronic device housing **12** using adhesive **62**. Adhesive **62** may be, for example, pressure sensitive adhesive.

Antenna window cap **56** may be attached to antenna support structure **38** using cured liquid adhesive **58**. Initially, adhesive **58** may be dispensed in liquid form, allowing antenna cap **56** to lie flush with housing **12** while absorbing size variations in support structure **38** and housing **12**. During the curing process, the outer surface of antenna window cap **56** (i.e., the lowermost surface of antenna window cap **56** in FIG. **5**) and the adjacent exterior surface of housing walls **12** (i.e., the lowermost housing surface in FIG. **5**) may be supported by upper surface **64** of assembly tool structure **60**. Structure **60** may be, for example, a metal tray or other structure that has a flat upper surface.

Biasing structures such as spring loaded pins **68** on assembly tool support **66** may press housing **12** and antenna window cap **56** downwards against surface **64** in direction **70**. Holes **52** in antenna support structure **38** (see, e.g., holes **52** of FIG. **4**) may allow pins **68** or other biasing members to pass through antenna support structure **38** to access the upper surface of antenna window cap **56**. By simultaneously supporting antenna cap **56** and housing **12** using surface **64** while adhesive **58** is cured and thereby transformed from its uncured liquid state to a solid cured state, antenna cap **56** may be mounted flush with respect to housing **12**.

As shown in FIG. **6**, assembly tool support **66** and assembly tool structure **60** may form part of a curing tray such as tray **80**. Support **66** may be mounted to spring-loaded arm **78**. A spring or other biasing mechanism may be used to bias arm **78** and structure **66** downwards in direction **70** (e.g., by rotating arm **78** about pivot axis **74** in direction **76**). Pins **68** may press downwards on assembly **72** (e.g., device structures such as housing wall **12** and antenna window cap **56** of FIG. **5**) during adhesive curing. As shown in FIG. **7**, tools such as tray **80** of FIG. **6** may be moved through an oven such as oven **82** using a positioner such as conveyor belt **86**. As tray **80** moves through oven **82** or is otherwise exposed to heat, liquid adhesive **58** (FIG. **5**) may be raised to an elevated temperature (e.g., 50-85° C., 75-85° C. or other suitable temperature) for sufficiently a long time (e.g., 10-30 minutes, less than 40 minutes, more than 20 minutes, etc.) to ensure that liquid adhesive **58** is cured. Once cured, liquid adhesive **58** attaches antenna window cap **56** to support structure **38**, thereby fixing the position of antenna window cap **56** relative to device housing **12**.

To prevent overflow of liquid adhesive **58** when attaching antenna window cap **56** to antenna support structure **38**, antenna support structure **38** may be provided with adhesive overflow channels such as channels **88** of FIG. **8**. Channels **88** may have the shapes of circular rings that surround holes **52** in support structures **38** or may have other shapes capable of receiving excess liquid adhesive. As shown in FIG. **9**, excess adhesive **58** may flow upwards in direction **90** into the recess in support structure **38** that is formed by channel **88** during adhesive curing operations. Channels **88** may help prevent adhesive **58** from becoming attached to moving parts such as spring-loaded pin **68**.

FIG. **10** is a cross-sectional side view of device **10** showing how structures in device **10** may be provided with electromagnetic shielding. As shown in FIG. **10**, display **14** of device **10** may have a display cover layer such as layer **92**. Layer **92** may be formed from clear glass, transparent plastic, or other suitable materials. An array of display pixels may be formed below cover layer **92**. As shown in the example of FIG. **10**, a display pixel array may be formed from layers such as thin-film transistor layer **96** and color filter layer **94**. Layers **94** and **96** may form part of a liquid crystal display (as an example). Display driver integrated circuit **98** may be used in routing display control and data signals to thin-film transistors on thin-film transistor layer **96**.

Printed circuits in device **10** such as printed circuit **106** (e.g., a main logic board or other printed circuit structures formed from one or more printed circuits) may receive components **108**. Components **108** may be, for example, integrated circuits, switches, connectors, filters, discrete components, and other circuitry.

Wireless circuitry in device **10** such as antenna structures **30** may be sensitive to interference from components **108** and display driver circuitry **98**. To reduce interference, conductive structures such as electromagnetic signal shield wall **102** and shield layer **100** may be used in forming electromagnetic shielding. As shown in FIG. **10**, this shielding may be used to prevent signals from display driver circuitry such as display driver integrated circuit **98** and from components **108** from reaching antenna structures **30**. Signals from antenna structures **30** or other components may also be prevented from reaching display driver circuitry **98** and other electrical components such as components **108**.

Shield wall **102** may be formed from a metal such as stainless steel (as an example). Shield walls such as shield wall **102** may be patterned using a stamping die, laser cutting, or other patterning techniques. Shield walls such as wall **102** may be oriented vertically as shown in FIG. **10**. As an example, walls such as wall **102** may be supported in a vertical orientation using plastic member **110**. One or more shield walls may be oriented at right angles with respect to each other to surround a sensitive component (e.g., to shield an antenna in a corner of device **10**). Shield walls such as wall **102** may, if desired, be attached to plastic member **110** by injection molding (insert molding) plastic member **110** over wall **102**. Plastic member **110**, which is sometimes referred to as a cover glass frame, may be attached to the inner surface of display cover layer **92** using adhesive **112**. Adhesive **112** may be, for example, a methacrylate-based liquid adhesive. Adhesive **58** for attaching antenna window cap **56** may also be a methacrylate-based liquid adhesive (as an example).

To form an effective electromagnetic shield, it may be desirable to use shielding wall **102** to form a vertical wall of conductor that extends between display cover layer **92** and housing **12**. As shown in FIG. **10**, for example, shielding wall **102** may be coupled to housing **12** using spring **120**, traces on printed circuit **106**, a metal structure such as a connector on printed circuit **106** (e.g., connector **114**), and conductive foam **116**. Housing wall **12** may be formed from anodized aluminum or other metals. To ensure formation of a satisfactory low-resistance contact between foam **116** and housing wall **12**, a portion of the anodization (aluminum oxide layer) on wall **12** may be removed by laser processing, thereby forming bare aluminum region **118**. Conductive foam **116** or other resilient electrical connection structures may form an electrical contact between region **118** and metal structure **114** on printed circuit **106**. If desired, other conductive pathways may be formed between shield wall **102** and housing wall **12**. The configuration of FIG. **10** is merely illustrative.

Shield layers such as shield layer **100** of FIG. **10** may be formed from a thin layer of conductor such as a thin flexible layer of metal (i.e., a metal foil). To minimize the amount of volume occupied within the interior of device **10**, it may be desirable to form shield layer **100** from a metal such as stainless steel that exhibits sufficient strength even at reduced thicknesses (e.g., thicknesses of less than 150 microns or even less than 20 microns). Stainless steel foil that is about 10 microns thick or other metal foils may be attached to metal structures in device **10** such as shield wall **102** using conductive adhesive, screws or other fasteners, using solder, or using welds. The use of welds may help to minimize contact resistance and thereby enhance the ability of shielding layer **100** and shielding wall **102** to form effective electromagnetic shielding within device **10**.

Shielding layer **100** may be formed from a sheet of stainless steel foil or other material that has a thickness of less than 150 microns, less than 100 microns, more than 70 microns, less than 70 microns, less than 40 microns, less than 20 microns, or less than 10 microns (as examples). To prevent tearing resulting from damage during welding, it may be desirable to use a sacrificial metal plate such as plate **122** of FIG. **11** in forming welds **124**. To promote satisfactory welding, the metals used for wall **102**, foil **100**, and plate **122** may be formed from the same metal (e.g., stainless steel). Plate **122** may have a thickness that is sufficient to allow plate **122** to donate material to welds **124** during weld formation, thereby preventing layer **100** from being excessively thinned and weakened during welding. Plate **122** may, for example, have a thickness of 0.05 to 0.15 mm.

FIG. **12** is an exploded perspective view of device **10** in an illustrative configuration in which shielding structures are used to reduce electromagnetic interference. As shown in FIG. **12**, device **10** may have housing portions such as housing portion **12**A and housing portion **12**B. In a completed device, housing portion **12**A may be attached to housing portion **12**B (e.g., by rotating housing **12**A in direction **128** about rotational axis **126** and by rotating housing **12**B in direction **130** around rotational axis **126**).

As shown in FIG. **12**, device **10** may have internal housing structures such as mid-plate member **131**. An edge of printed circuit board **106** may protrude from under mid-plate **131**. Springs **120** may be soldered to printed circuit board solder pads along the edge portion of printed circuit board **106**. When housings **12**A and **12**B are assembled, springs **120** may mate with contact regions **132** on shielding wall **102**. Welding locations **134** on wall **102** show where shield layer **100** (not shown in FIG. **12**) may be attached to shield wall **102**.

Shield walls **102** and **102'** may run perpendicular to each other and may be supported by plastic support structure **110** (e.g., by insert molding walls **102** and **102'** within the plastic of structure **110**). Antenna support structure **38** may be provided with a metal structure such as jumper plate **138**. Jumper plate **138** may be formed from a sheet of stainless steel or other metal and may be attached to support structure **38** using screws that pass through plate **138** and support structure **38** and that are received by threaded portions of housing **12**A. A sheet of stainless steel or other metal layer may be used to form shielding layer **100'**. Shielding layer **100'** may, for example, be formed from the same type of thin metal that is used in forming shielding layer **100**. When housings **12**A and **12**B are assembled, contact regions **140** on plate **138** may contact regions **136** on shield wall **102'** (e.g., using interposed conductive foam).

FIG. **13** is a cross-sectional side view of shielding layer **102'** showing how a sacrificial plate (e.g., a plate formed from a stainless steel sheet having a thickness of 0.05 to 0.15 mm) may be used in welding shield layer **102'** to jumper plate **138**. Conductive foam **142** may be interposed between shielding layer **102'** and shield wall **102'** to form an electrical connection between wall **102** and jumper plate **138**. Jumper plate **138**, in turn, may be electrically connected to housing **12**A via screws or other conductive structures.

An exploded perspective view of a portion of device **10** showing how antenna structures **30** may be mounted to support structure **38** using a support plate is shown in FIG. **14**. As shown in FIG. **14**, housing **12** may have alignment features such as ribs **166** and **168** that are configured to mate with corresponding alignment features on support structures **38**. When antenna support structure **38** is installed in housing **12** of device **10**, rib **170** may rest against rib **168** of housing **12** and ribs such as rib **164** of support structure **38** may rest against ribs on housing **12** such as rib **166**.

Support structure **38** may have alignment features such as alignment holes **160** that receive mating alignment features such as alignment posts **158** on antenna support plate **150** when antenna support plate **150** is mounted on top of antenna support structure **38**. Biasing structures such as foam structures **162** may be used to bias plate **150** and antenna structures **30** upwards in direction **172** towards display cover layer **92** (FIG. **10**). Antenna structures **30** (e.g., a flexible printed circuit containing antenna traces) may be mounted to an antenna support structure such as antenna support plate **150** using adhesive or other suitable attachment mechanisms. Plate **150** may help maintain antenna structures **30** in a desired shape. Due to the presence of alignment posts **158**, plate **150** may help antenna structures **30** resist lateral motion in directions **174** and **176**, thereby helping to ensure that antenna structures **30** are located where desired.

During assembly operations, an alignment tool such as an alignment tool with alignment pins **156** may insert pins **156** through both holes **154** on antenna structures **30** and mating holes **152** on antenna support plate **150**. This ensures that antenna structures **30** will be properly aligned with respect to antenna plate **150** along lateral dimensions **176** and **174**. Adhesive or other suitable fastening mechanism may be used to attach antenna structures **30** to antenna support plate **150**. FIG. **15** is a cross-sectional side view showing how alignment pins **156** may be used during assembly to ensure that antenna structures **30** are aligned with respect to antenna support plate **150**. Protrusions such as antenna support plate alignment posts **158** or other alignment features may be used to ensure satisfactory alignment between antenna support plate **150** and antenna support structures **38**. Following mounting of antenna support plate **150** to antenna structures **138**, alignment members **156** may be removed. Display cover layer **92** may then be mounted on top of antenna structures **30**.

The foregoing is merely illustrative of the principles of this invention and various modifications can be made by those skilled in the art without departing from the scope and spirit of the invention. The foregoing embodiments may be implemented individually or in any combination.

What is claimed is:

1. Apparatus, comprising:

an electronic device housing having a hole;

an antenna window cap in the hole;

an antenna support structure that is attached to the electronic device housing; and

a layer of adhesive that attaches the antenna window cap to the antenna support structure.

2. The apparatus defined in claim **1** wherein the antenna support structure comprises at least one hole adjacent to the antenna window cap.

3. The apparatus defined in claim **2** wherein the antenna support structure comprises an adhesive overflow channel surrounding the hole.

4. The apparatus defined in claim **3**, wherein the adhesive overflow channel surrounding the hole comprises a ring shaped overflow channel in the antenna support structure that surrounds the hole.

5. The apparatus defined in claim **3**, wherein a portion of the layer of adhesive is formed within the adhesive overflow channel surrounding the hole.

6. The apparatus defined in claim **1** further comprising antenna structures mounted on the antenna support structure.

7. The apparatus defined in claim **6**, wherein the antenna structures comprise a printed circuit board mounted on the antenna support structure and patterned metal antenna traces on the printed circuit board.

8. The apparatus defined in claim **7**, wherein the printed circuit board comprises a flexible printed circuit board.

9. The apparatus defined in claim **1** further comprising a layer of pressure sensitive adhesive that attaches the antenna support structure to the electronic device housing.

10. The apparatus defined in claim **1** wherein the electronic device housing comprises a metal housing.

11. The apparatus defined in claim **10** wherein the layer of adhesive comprises cured liquid adhesive.

12. The apparatus defined in claim **1**, wherein the antenna support structure comprises a dielectric antenna support structure.

13. The apparatus defined in claim **12**, wherein the dielectric antenna support structure comprises injection-molded plastic members.

14. The apparatus defined in claim **12**, wherein the electronic device housing comprises a conductive electronic device housing and the dielectric antenna support structure is attached to the conductive electronic device housing using an additional layer of adhesive.

15. The apparatus defined in claim **12**, wherein the dielectric antenna support structure comprises rib structures that separate a plurality of air-filled cavities within the dielectric antenna support structure.

16. The apparatus defined in claim **15**, wherein the dielectric antenna support structure comprises a first hole formed between a first air-filled cavity of the plurality of air-filled cavities and the antenna window cap.

17. The apparatus defined in claim **16**, wherein the dielectric antenna support structure further comprises a second hole formed between a second air-filled cavity of the plurality of air-filled cavities and the antenna window cap.

18. Apparatus, comprising:

a conductive electronic device housing;

a dielectric antenna window structure in the conductive housing;

an antenna support structure that is attached to the dielectric antenna window structure; and

adhesive that attaches the antenna support structure to the conductive electronic device housing.

19. The apparatus defined in claim **18**, further comprising:
an adhesive layer that attaches the antenna support structure to the dielectric antenna window structure.

20. The apparatus defined in claim **18**, wherein the antenna support structure has opposing first and second sides, wherein the adhesive is formed between the first side and the conductive electronic device housing, the apparatus further comprising:
a printed circuit board mounted to the second side of the antenna support structure; and
metal antenna traces on the printed circuit board.

21. The apparatus defined in claim **20**, further comprising:
an adhesive layer formed between the first side of the antenna support structure and the dielectric antenna window structure.

22. The apparatus defined in claim **21**, wherein the antenna support structure comprises at least one hole at the first side and an adhesive overflow channel surrounding the hole at the first side.

23. Apparatus, comprising:
a housing for an electronic device, wherein the housing has a hole;
a dielectric antenna window structure in the hole; and
an antenna support structure that is attached to the housing and that is attached to the dielectric antenna window structure, wherein the antenna support structure is configured to fix a position of the dielectric antenna window structure relative to the housing.

24. The apparatus defined in claim **23**, wherein the housing comprises a conductive housing structure and the antenna support structure comprises a dielectric antenna support structure, wherein the dielectric antenna support structure is attached to the conductive housing structure and the dielectric antenna window structure.

25. The apparatus defined in claim **24**, wherein the dielectric antenna support structure is attached to the dielectric antenna window structure in the hole using a layer of adhesive.

26. The apparatus defined in claim **25**, wherein the dielectric antenna support structure is attached to the conductive housing structure using an additional layer of adhesive.

27. The apparatus defined in claim **26**, further comprising a printed circuit board mounted onto the dielectric antenna support structure and having patterned conductive antenna traces.

* * * * *